TEACHING ‘DIGITAL EARTH’ TECHNOLOGIES IN ENVIRONMENTAL SCIENCES

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ABSTRACT:

As part of a review process for a module entitled 'Digital Earth' which is currently taught as part of a BSc in Environmental Sciences program, research into the current provision of Geographical Information Science and Technology (GIS&T) related modules on UK-based Environmental Science degrees is made. The result of this search is used with DiBiase et al. (2006) 'Body of Knowledge of GIS&T’ to develop a foundation level module for Environmental Sciences. Reference is also made to the current provision geospatial analysis techniques in secondary and tertiary education in the UK, US and China, and the optimal use of IT and multi-media in geo-education.

1. INTRODUCTION

1.1 Background

A module introducing technologies related to the ‘Digital Earth’ concept (as described by Craglia et al., 2008; Goodchild et al., 2012) is delivered as part of a BSc Environmental Science programme at the Department of Geographical Sciences at the University of Nottingham Ningbo China (UNNC). The module aims to raise awareness of the increasing importance of digital geographic information (DGI) in monitoring and modelling environmental processes, but also to provide the foundation for subsequent study of fundamental and advanced-level of Geographic Information System (GIS) and Remote Sensing (RS). Particular attention is given to the application of DGI within the disciplines of hydrology, ecology, environmental impact assessment and climate change. A secondary aim of the module is to introduce a range of datasets that can be used to investigate environmental issues, and a critical appreciation of such data that will allow appropriate usage within geospatial modelling and visualisation.

A review of the module was made in summer 2013 as part of a teaching development exercise at UNNC. This paper describes the research and conclusions that informed that review process.

2. DIGITAL EARTH AND ENVIROMENTAL SCIENCES

2.1 The ‘Digital Earth’

The concept of the ‘Digital Earth’ was first introduced by Al Gore in his book ‘Earth in Balance’ (Gore, 1992) and further developed in a speech made at the California Science Centre in 1998 (Gore, 1998). It describes the idea of a three-dimensional digital replica of the planet earth that can allow real-time visualisation and manipulation of complex data layers at both global and local scale. The development of a number of prototype models led to the eventual launch of the Google Earth service in 2005, the adoption of which, by both scientific and educational communities, has been part of a wider expansion and development of geospatial applications and data. Interestingly however, whilst the use of DGI and related platforms has seen widespread use and application within Environmental Sciences at the local, regional and national scale, Yu and Gong (2011), suggest that research at a global scale is still in need of analysis procedures that integrate real-time data from in-situ measurements, remote sensing and GIS.

Thus, as the demand for increasingly complex DGI and GIS related tools increases, so too does the demand for skilled professionals within those fields. In response to this increasing demand, the University Consortium for Geographic Information Science (UCGIS) in the United States has offered a comprehensive description of the nature, diversity and state of the discipline (which it defines as Geographic Information Science and Technology (GIS&T)); and suggests that it be used to inform national curriculum planning for secondary to undergraduate and postgraduate level education (DiBiase, 2006). It is with both this expansion and new guideline for definition of the discipline and in mind that the ‘Digital Earth’ module at UNNC was reviewed.

2.2 Provision of Geospatial Sciences in Education

The degree to which students can attain advanced level skills in a GIS&T discipline during a three or four year undergraduate level course at university is to some extent determined by their pre-university exposure to geospatial related concepts. Whilst GIS is now used widely within secondary education across the globe, the application and optimal use of such systems is not always obvious to pupils at this stage of their education (Ruepert, 2009).

In China for example, Dong and Lin (2012) noted that the teaching of geographic and related spatial concepts is not new, and that many high-school students (particularly within Geography) obtain a basic knowledge of GIS whilst still at

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school. However, they also suggest that GIS implementation within schools is at least in-part driven by the push for increasing use of technology in the classroom, rather than based on demand for GIS, per se. Indeed, many classes within Chinese schools are still taught by instruction and demonstration, rather than student-cantered activities, thus negating the opportunity for students to gain hands-on experience.

DiBiase et al., (2006) indicated their concern about the ‘preparedness’ of the workforce entering careers in, or related to, the provision of GIS&T services. In particular, they highlighted the existence of ‘low-level, non-technical’ GIS education in undergraduate degree programs (as first described by Marble (1998)), and suggest that ideally all undergraduate degrees should prepare students to achieve all levels of Marbel’s ‘pyramid of competency levels’ within GIS (see Figure 1). We would therefore expect most undergraduate courses specialising in GIS to attain level 4 of the pyramid by the end of the program (application, design and development of GIS systems).

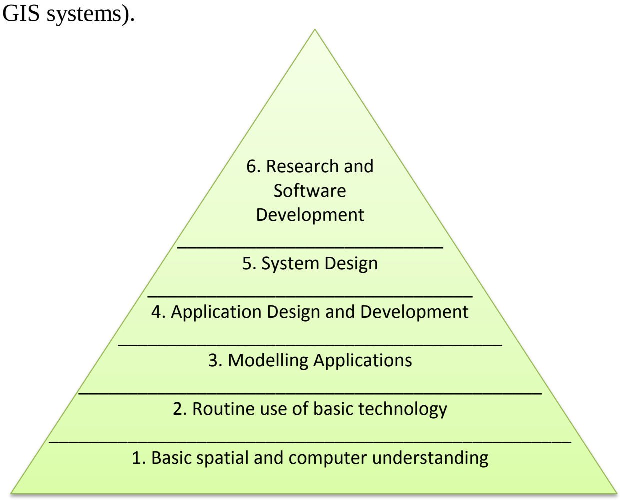

Figure 1 Marble’s (1998) pyramid of competences for GIS.

In order to prepare students for entrance into a GIS&T related undergraduate program then, secondary school education would ideally be achieving the first level of Marble’s pyramid before they reach university (basic spatial and computer understanding). However, in educational institutes where compatible academic options (such as Geography, Technical Drawing, Geospatial Technology, etc.) are not offered, students may not reach this level and be forced to ‘catch-up’ once at university and as a result find it harder to reach the upper levels of the pyramid.

Within this context then, it is proposed that a student choosing geospatial science options within an Environmental Science degree should be able to achieve at least level 3 of Marble’s pyramid (application of higher level modelling). This would provide a foundation for application of geospatial concepts and techniques within Environmental Sciences, and the potential for students to progress to higher levels via related post-graduate education.

To assess the current provision of geospatial related teaching within Environmental Science degrees in the UK, the University and Colleges Admissions System (UCAS) was used to identify GIS&T related modules within degrees entitled ‘Environmental Science (or Sciences)’. Out of thirty-seven degree programs identified, it can be seen (in Figure 2), that 57% offer modules in GIS modules, 32% offer modules in Remote Sensing and 11% offer modules in another geo-spatial subject. 30% of courses had no provision for any GIS&T (unless it was included under the provision of more general ‘methods and analysis’ type modules). Courses that provided geo-spatial related modules, usually did so in the first and second year of study, presumably so that students could utilise these skills within the final year of study. Just four of the courses reviewed offered modules in all three years, at levels ranging from fundamental to advanced. It was also found that 30% of courses offered both GIS and Remote Sensing modules.

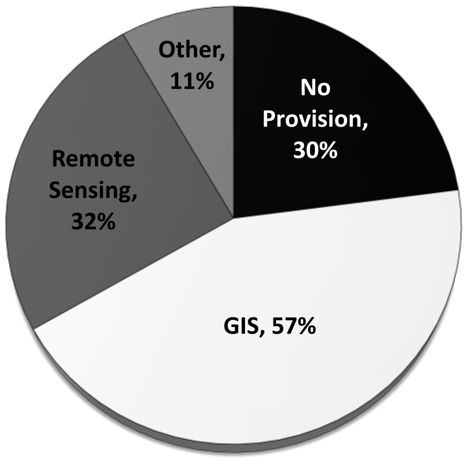

Figure 2 Percentage of UK BSc Environmental Science(s) degrees with dedicated GIS&T modules.

GIS&T modules in the current syllabus of the Environmental Sciences degree at UNNC are shown in Table 1. Although only a three-year programme, a fourth year which represents Master’s level study in GIS is delivered in the UK, is included for completeness as it can be seen as a natural progression for those students wishing to continue their study in the same institution. It can be seen that the ‘Digital Earth’ module, the review of which is the focus of this paper, lies at the foundation level across the field of both GIS and remote sensing, as it is aims to deliver basic introductory theory and methods to both disciplines.

Table 1 GIS&T modules offered to Environmental Science students at University of Nottingham.

	GIS	**Remote Sensing**	**Other Geo-spatial**
Masters Level	Professional GIS	Advances in Remote Sensing	Geospatial Information Services
	Fundamentals of GIS		Geospatial Technologies
			Spatial Data Handling
Year3	Mobile and Field GIS	Remote Sensing of Environment	Geospatial Technologies
Year 2	Digital Explorers	Earth Observation	
Year 1	Introduction to GIS		
	The Digital Earth		

When the content of the modules shown in Table 1 were compared with DiBiase et al., (2006) 'Body of Knowledge' descriptions of GIS&T it was found to offer a high degree of coverage of topics within the classes of 'Analytical Methods', 'Data Manipulation and 'Geo-spatial Data'; medium degree of coverage in the classes of 'Conceptual Foundations', Data Modelling' and 'Geo-computation' and low coverage of 'Design Aspects', and 'GIS&T and Society'. Although only a qualitative measure, it can be seen that the degree program covers the more pragmatic and application-orientated aspects of the curriculum as defined by DiBiase et al., as opposed to 'GIS&T and society' or 'organisational and institutional aspects'.

3. MODULE DEVELOPMENT

The idea for a module entitled 'Digital Earth' was conceived at the University of Nottingham UK campus (School of Geography). The aim of the module was to introduce students to a range of digital technologies currently used within Geographical Sciences. Emphasis was given to understanding different geo-spatial monitoring, modelling, and visualisation techniques. The module has been delivered at the University's China campus in Ningbo, Zhejiang since 2011.

3.1 Student Feedback on existing Module at UNNC

Comments made by students in module feedback forms in the academic years 2010/11 and 2011/12 were generally positive, with over 80% stating that they 'strongly agreed' with the positive aspects of the module (indicating that the course was well organised with clear objectives, and developed their understanding of the topic and related concepts). Comments on the feedback form were also positive, particularly with respect to the use of multi-media learning materials within the module lectures and practical classes. Typical comments included expressions like:

"…videos make content more understandable"
"…videos provide much more (sic) information"
"…videos are an effective way of teaching this material."

During personal communication with students, after lectures or in tutorials however, a number of students said they had difficulty in contextualising some of the module content within the aims of their larger degree. In particular, some of the material that addressed economic or cultural issues was seen as less relevant to Environmental Scientists: For example 'the use of GIS for economic analysis' and 'the development of virtual reality for social interaction'.

It was also found that some multi-media resources (for example, full length video recordings of lectures provided for independent study and revision), were not well utilised. Indeed, most students felt that any fifty-minute video was not something that they were likely to be able to use easily. Part of the difficulty was that students felt unable to fast forward to the 'important bits', and as a result preferred to use their time more effectively through independent reading. It was indicated however, that a short summarised version of lectures would be useful. For example, a collection of subject-referenced 'sound-bites', edited from the original lecture material would be particularly well-received.

Because of the interdisciplinary nature of the module and the fact that is a relatively new area, the lack of easily accessible reference material to support lectures, was also indicated as being an issue by some students. A number of students also indicated that the practical component within the module should be higher.

3.2 Review of related literature

As a result of the above feedback, a review of literature describing teaching techniques and module design within geographical and spatial sciences was undertaken. A number of the UK Higher Education Academy (Engineering Subject Centre) guides were useful in identifying reference material for teaching design (Case, 2010); teaching international students (Bond and Scudamore, 2010) and environmental studies (Xu, 2003; Penlington and Steiner, 2010). John Biggs' idea of 'constructive alignment' in module design (Biggs, 1999); and Jenny Moon's thoughts on the link between assessment criteria and learning outcomes (Moon, 2002), were particularly useful in providing the structure for assessment exercises.

3.2.1 Multi-media in teaching GIS&T: Much previous research on the use of different multi-media learning materials has focussed on the type, format and style, and how they can best be used to supplement and improve the learning process. The University of South Carolina (2013) and Cisco Systems (2008) in particular, provide useful reviews of multimodal teaching using different types of media. With respect to the mix of multi-media resources used within teaching of GIS&T subjects, reference can be made to Edgar Dale's 'Cone of Experience' concept, which suggests that different types of audio, visual and tactile materials can be used to assist the learning process (Dale, 1954). This in turn suggests that practical-based activities (such as those regularly performed within GIS or remote sensing exercises), can result in more effective comprehension and retention of new information, compared to a simple verbal description of the same activity. However, it should be noted that the concept is a general one and cannot always ensure increased learning efficiency. A 'hands-on' practical demonstration of different map symbologies for example, may not always be the most efficient method of teaching students the definitions of over one-hundred map-symbols.

The use of information technology to facilitate teaching and associated learning materials is not new. Sieber (2005) for example, is one of many educationalists who noted that more effective learning can be achieved in classrooms that have computers, as they can be used to provide more graphic illustrations and learning opportunities than in more traditional classrooms. Computers are also necessarily more interactive than other learning methods. Hughes (2005) notes however, that it is not enough to just direct students to a computer-based learning resource. They should first be supplied with appropriate 'information strategy' skills that enable them to compare and evaluate different types of information and then synthesise and create new information of their own. Such 'information strategy' skills include basic things like information recognition, search strategy formulation and information navigation skills.

With respect to the provision of supplementary learning materials, Salmon and Edirisingha (2008), found that short videos (or 'podcasts') can help students to engage with their studies more often and less formally 'in just the same way that they listen to their music'. This somewhat echoes Briggs' (2003) assertion that the use of 'educational technology' can be either ‘synchronous’ or ‘asynchronous’: meaning that learning can occur both directly, as a real-time interaction within the classroom, or subsequently during the students’ own-time outside the classroom. This concept is a useful one that can be used to promote ‘independent learning’ and the formulation of individual learning strategies, as it reinforces the fact that learning can take place at a pace and location that is determined by the student themselves.

3.2.2 Practical exercises in GIS&T: The design of the practical exercises for learning is seen as critical, both as an aid to understanding new concepts and to allow students to gain ‘hands-on’ experience of new technologies. In designing practical classes GIS&T, one of the challenges is to present technical procedures in an engaging way so that it does not just become a button pressing exercise. Cox (1994) indicates that this can be achieved by concentrating on communication and motivation. Practical exercises can be designed as activities through which the student can lead themselves. This approach requires the topic and the objectives of each exercise to first be outlined by the trainer, to create a framework within which students can then work (*communication*). The student should also be told what s/he is about to learn, and how they will be able to apply it in the future (*motivation*). Practical exercises can also be designed to move through Bloom’s taxonomy of educational objectives (1956): comprehension; application; analysis; and evaluation. The learning objectives of each of these stages can also be made clear to the students both at the start and the end of the class. To facilitate easier monitoring of student progress, students can be asked to complete individual sub-tasks before moving on. In this way it becomes possible to identify students struggling to complete specific tasks.

4. DESIGN OF THE NEW MODULE

After reflecting on student feedback and literature related to the delivery of practical-based subjects, a review of module structure and content was made, including redesign of a number practical exercise.

4.1 Lecture Content

Whereas the original module focussed on emerging technologies being used within geo-spatial study, the new module focuses on the use and application of GIS&T techniques. This was achieved by including lectures that relate specifically to monitoring, modelling and management of the environment through the use of geo-spatial measurement and analysis methods (see new module outline in Table 2). The module then is based around the concept of the development of ‘Digital Earth’ related technology and use. This concept is first introduced to provide context. The range, format and availability of global and national datasets (China and UK) are then reviewed along with an introductory lecture to ‘Earth Observation’ (or remote sensing). A review of data sampling methodology and protocols is then made, followed by consideration of data format, compatibility and uncertainty. The potential use of environmental data in modelling and visualisation is then presented, before consideration of the future challenges and opportunities.

It is hoped that the new lectures and module structure will encourage students to investigate the links between the different approaches and geo-spatial techniques, and how they will use them when they are either in the work environment or go on to study for a higher degrees.

Table 2 Module Outline

Topic	Details
The Concept of a Digital Earth	What can Google Earth and other virtual globes offer now and in the future, and do these technologies promise to help tackle global problems as envisaged by Al Gore.
Global Data Sources	Review of online global environmental data sources and their use within environmental sciences. Includes soil, land-cover, hydrology, meteorology, and geology data.
UK and Chinese Data Sources	A comparison of environmental data availability, quality and use between UK and China, highlighting the differences in methods of environmental data provision and the extent of publicly available data.
Data Collection Process	How should we approach desk Studies and baseline assessments? Sampling strategies for collecting data, and the use of mobile and remote monitoring techniques. Quality assurance and managing uncertainty.
Application and use of DGI	How compatible are different digital environmental data-sets? Discussion of the use of digital data-sets and related issues; integration of digital data (and formatting issues); geo-statistics and uncertainty.
Earth Observation	What can Earth Observation offer now, and what are the prospects for the future? Recent advances in remote sensing of the Earth and the potential of new data sources and technologies are reviewed.
Modelling Earth Dynamics	What are the research challenges in modelling scale and dynamics of land cover and Earth surface processes? A review of latest developments in environmental science.
Virtual Landscapes	To what extent can the Earth's surface, and objects on that surface, be represented faithfully in digital form? A review of visualisation techniques for the earth’s surface.
Case Studies	Integration of virtual globes, earth observation, GIS and the web and related tools for sharing, analysing and visualising digital geographic information.
Future Trends	A look at future provision and distribution of environmental data. What are the obstacles to greater integration of existing digital data?

The new module was first delivered in spring 2013. Lectures were recorded using the ‘*Echo360*’ software which can be used to edit the lectures to create 'sound-bite' .mp4 files (with run times less than 10 minutes). These will be made available to students using the course management system software, *Moodle.* Both these software will allow students greater access to course materials and as a result, greater control over their study. A number of lectures were also presented using the '*Prezi'* presentation software (see screen-shot in Figure 4). This software allowed greater flexibility in presentation of large visual data-sets such as remote sensing satellite imagery (the zoom capability is particularly useful in this context). It also allowed students to see more clearly the linkages between different concepts or ideas in the same manner as a 'mind-map'. Feedback from students indicated that this medium for presenting geo-spatial information was preferable to .ppt slides.

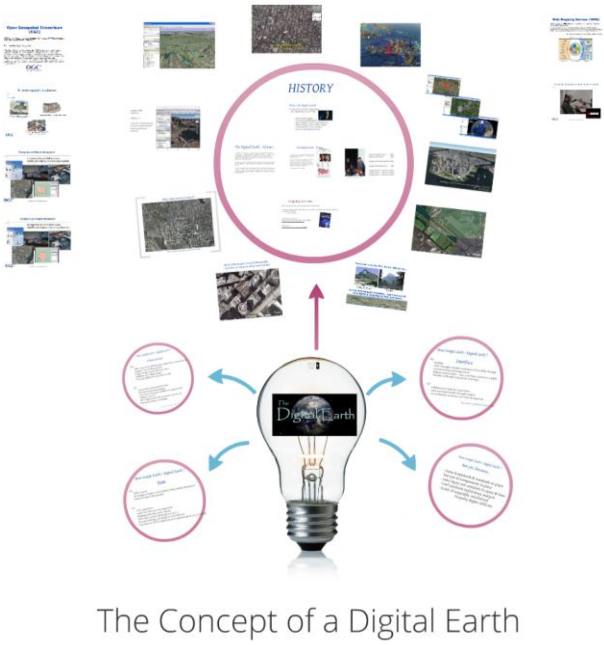

Figure 3 Prezi screenshot of introductory lecture

4.2 Practical Classes

Practical classes for the module were designed to reinforce the acquisition of new geospatial information and skills. This was achieved using locally relevant data sets (for better engagement of students), and by guiding students to use the data manipulation and analysis techniques that had been previously introduced within lectures (see Table 3 for practical class schedule). Practical classes were also designed to prompt students into thinking about how they might use the acquired skills in the future.

Table 3 Practical-class topics

Lecture	**Practical**
Global data sources	Identification, downloaded and comparison of SRTM and ASTER satellite.
UK and Chinese Data Sources	Geo-referencing geological data for Ningbo, and using SRTM data as a base map.
Data Collection Process	Analysis of field and remotely sensed data collected at different sampling frequencies to assess different properties
Application and use of DGI	Interpolation of sampled soil data using inverse-distance weighted spline and kriging.
Earth Observation	Viewing and analysis of Landsat-5 imagery using ARCGIS and Google Earth.
Modelling Earth Dynamics	Use of a number of simple physically based runoff models and associated visualisation techniques.
Virtual Landscapes	Use of Google Earth and Sketch-Up to produce landscape visualisation for an impact assessment of a wind-farm in a national park

5. CONCLUSION

This review of the 'Digital Earth' module at UNNC was conducted to help students contextualise the study of GIS&T within their wider degree in Environmental Science. During this process, consideration of course design; structure and content of lectures and practical classes; and the use of multi-media resources in teaching were made. Reference has been made in particular to DiBiase et al. (2006) and Marble (1998) and the concepts of a body of knowledge for GIS&T, and the pyramid of competences for GIS, respectively. A range of teaching theory literature relating to the use of IT within teaching has also been made.

Quite early in the process, it became clear that a coherent module design with clear learning objectives that were linked to specific lectures could help students to both fully appreciate the range of skills that they were are learning, and how they might use them in the future. The design of new lectures was guided by the need to provide a solid foundation in a range of geo-spatial competences including spatial analysis techniques, GIS, remote-sensing, visualisation, and modelling. This would allow even students not previously exposed to geospatial analysis techniques to progress to upper levels of competency within this field should they wish. Practical classes were designed to support lectures by the use of relevant (local) material, designed to engage and simulate students to conduct independent study outside of the classroom.

Whilst the creation of multi-media teaching resources has become more frequent in recent years (particularly within the field of GIS&T), the use of such resources at appropriate times and within the right context has become a greater challenge. Whilst the use of multi-media lends texture and variety to classes, potentially leading to increased retention, it has been shown that students generally react better information that can be readily accessed from anywhere and at any time. However, the role of communication, personal involvement and motivation within practical work is seen as most critical in cultivating student empowerment and independent learning.

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